DESIGN A PHOTOVOLTAIC SYSTEM BASED ON MAXIMUM POWER POINT TRACKING UNDER PARTIAL SHADING

USAMA ABDULLAHI MA'ALLIN

A project report submitted in partial
fulfilment of the requirement for the award of the
Degree of Master of Electrical Engineering

Faculty of Electrical and Electronic Engineering
Universiti Tun Hussein Onn Malaysia

JANUARY 2019

To my father and mother...

ACKNOWLEDGEMENT

First, I want to thank God for the guidance and protection I have given in my life. I would also like to thank the University of Tun Hussein Onn Malaysia and the School of Electrical and Electronic Engineering (FKEE) in Malaysia for giving me the opportunity to gain valuable skill and acquaintance. Most importantly, excellent facilities, tools and adequate equipment are very popular in the lab.

I would also like to thank my supervisor Dr. Mohd Noor Bin Abdullah for his assistance, guidance and encouragement to complete my project. Without his guidance and knowledge, I will not be able to complete this report. He did everything possible to ensure that under his supervision I understood the complete concept of the project.

Also, I send my dedication father and mother, who always have your hearts with me, and their prayers have led to the lighting of my daily life. Thank you for everything, I appreciate your patience and unlimited support for me. I would also like to thank my brothers and sisters, friends, family and all those who helped to complete this project.

ABSTRACT

Photovoltaic systems have been given special attention given their long-term potential advantages. Solar panels can produce maximum power at specific operating points called maximum power points (MPP). Solar panels must work at this particular stage in order to ensure that solar panels produce maximum power and maximize efficiency. The performance of the solar photovoltaic unit is strongly affected by the level of radiation, heat and partial shading condition. The partial shedding condition is one of vectors that can affect the PV cell performance. To overcome on this problem, this project proposes photovoltaic system based on maximum power point tracking of partial shading condition. The MPPT algorithm has many methods like P&O and PSO. P&O it had limitation that is not capable to cover the multi-peaks curves. Beside that the PSO method is more effective in partial shading condition. The voltage and current of MSX60 PV module are subjected to various insolation conditions. The Particle Swarm Optimization (PSO) algorithm based MPPT has been implemented to track maximum power partial shading condition. So, in normal condition the power reach 245 W which is higher than the power under partial shading condition that reach 100 W. The PV module is designed using MATLAB/SIMULINK. The accurateness of this simulator is verified with PV module, the result is practiced during normal condition and under partial shading condition meanwhile, multiple curves of I-V and P-V will produce during normal condition and partial shading condition.

ABSTRAK

Sistem kuasa fotovoltan telah mendapat perhatian khusus kerana potensi manfaat jangka panjangnya. Panel solar dapat menghasilkan kuasa maksimum pada titik operasi tertentu dipanggil Maximum Power Point (MPP). Untuk memastikan panel solar menghasilkan kuasa yang maksimum dan mendapatkan kecekapan maksimum, seluruh sistem panel fotovoltan mesti beroperasi pada titik khusus ini. Penulisan ini mencadangkan sistem fotovoltan berdasarkan pengesanan titik kuasa maksima pada kawasan panel yang dilindungi oleh bayang atau hanya sebahagian kawasan tersebut dilindungi bayang. Prestasi modul solar fotovoltan sangat dipengaruhi oleh tahap radiasi matahari, suhu dan teduhan separa. Lembaran data termasuk voltan dan arus bagi modul MSX60 PV tertakluk kepada pelbagai tahap radiasi matahari. Data yang dikumpul kemudiannya digunakan untuk membangunkan algoritma PSO berdasarkan MPPT untuk mengesan tingkahlaku sebenar modul PV. Hal ini untuk memastikan kuasa maksimum dapat dijana daripada modul PV kepada beban. Sistem ini kemudiannya direka bentuk menggunakan MATLAB/SIMULINK.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

C1	-	Personal Learning Coefficient
C2	-	Global Learning Coefficient
DC	-	Direct Current
I_{sc}	-	Short Circuit Current
I-V	-	Current -Voltage
KW	-	Kilo Watt
Kw/M^2	-	Kilo Watt Per Meter Square
MPPT	-	Maximum Power Point Tracker
Ns	-	Number of Series
NP	-	Number of Parallel
Pmp	-	Peak Maximum Power
PSO	-	Particle Swarm Optimization
P&O	-	Perturbed and Observation
P-V	-	Power – Voltage
Rs	-	Series Resistance
Rsh	-	Shunt Resistance
STC	-	Standard Test Condition
Voc	-	Open Circuit Voltage
w/m^2	-	Watt Per Meter Square

CHAPTER 1

INTRODUCTION

1.1 Background of the Project

With the world potential economic crises and increasing demand for energy, it will be something uncomfortable that civilized society is almost completely depends upon fossil fuels which are finite source. Instead of that, the world moved to alternative source which is inexhaustible and non-polluting source and is called renewable energy [1].The most prominent sources in developed countries uses are sources from the sun, wind, hydro, nuclear and energy that generating from the wave ocean. However, each source of renewable energy has unique benefits, costs and policies, for instance the countries wiling to develop nuclear energy has to deal with various issues such as nuclear weapon, accident risk in the plant for the environment and difficulties to dispose the nuclear waste. Hence the most suitable energy sources that can be used is energy from the sun [2]. The sun is the star that dominates our solar systems which makes solar energy most practical type of energy due to plentiful availability. As the sun's energy hits down to the earth, approximately 70 % of it gets back by the land and oceans, while 30 % is reflected into space. The energy radiation from the sun can be utilized mainly in two forms:

- Solar cell is an electrical device which are using source of photovoltaic effect in which the light energy is converted into electricity.
- Solar cells are using solar collectors for accumulating the energy coming from sun.

.

The efficiency of the solar thermal is high because no energy transformation is needed, for the PV cell the sun light penetrates the semiconductor material as shown in Figure 1.1 and generates electricity for transformation of the sun.

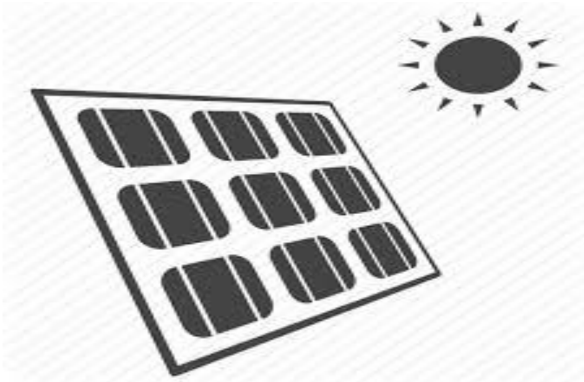

Figure 1.1: PV cell

In general the PV cells used to day can generate electricity with efficiency around 11-15%[2].Researchers are continuously trying to further upgrade the efficiency of solar cells while also giving effort for analysing the amount of light entering to the cell, for silicon is a naturally shiny material and cells are coated with non-reflective layers to make sure that as much light as possible penetrates to the cell. Although the efficiency of solar cell is approximated 15%, not included environmental constrains effect such as radiation, temperature and shading. The PV plant can experience partial shading condition which diminishes the photovoltaic efficiency as shown in Figure 1.2.

Figure 1.2: PV plant

Solar panels clearly produce less power when they are covered partially, and there may be a situation where this cannot escape, and effects should be considered, therefore PV designers need to think to avoid this effect. Because of that Simulator is needed to ensure maximum power extraction during partial shading, PV inverter should be equipped with intelligent MPPT tracker. Therefore, to design a perfect MPPT tracker for a PV array system that can track the maximum power point (MPP) under partial sheading conditions is required. A fast PV array system is needed to study the dynamic behavior of the MPPT tracker. The designer should study the MPPT algorithm through simulation process before applying in real hardware.

1.2 Problem Statement

In a short term is expected that photovoltaic energy will be one of the fastest growing market. This growth creates new problems for manufacturers since testing many photovoltaic modules before installation is complicated. Currently testing for the connected equipment, such as inverters, use as real panel. This leads to a problem, since the oscillations of temperature, radiation and partial shading effect is difficult to isolate the variables that affect the panel performance. So, to make sure that the maximum power is extracted during partial shading; PV inverter should be equipped with intelligent MPPT tracker. Therefore, to design a good PV system capable of reducing PS conditions effect is needed. Despite the existence of various types of simulators for homogenous PV systems, there is still no PV simulator for MPPT tracker that able to emulate partial shading condition in MATLAB\Simulink®, and no simulator can allow to analyse gradual change in period for partial shading condition, even if there is, it will be very slow and randomly. Because modelling partial shading condition in PV systems is more complex and time consuming. Therefore, the developed design, would be the midpoint in order to perform these measurements, based on the characteristics of the panel in partial shading, by giving constant values of voltage, power and current, in order to identify the inverters needed for installation. The user then can identify the factors that affect performance of the panel, analysing the resulting curve by changing variables. Thus, it is also more accurate measurements made in other components connected to the photovoltaic panel. This design also allows you to test hundreds of panels without having to purchase them, besides being able to control their response to various partial shading conditions. The design can also calculate the maximum power point Tracking (MPPT) of the photovoltaic module chosen, with the desired environmental conditions. The major contribution of this simulator is to analysis partial shading condition for gradual change in any period in simple, fast and accurate.

Thus, in this work needs to improve a PV system that can equipped with MPPT algorithms and power converters.

1.3 Objectives

i. To design a photovoltaic system based on one diode model using MATLAB.
ii. To develop a module capable of simulation and analysis of PV module under various partial shading conditions.
iii. To improve a photovoltaic system with maximum power point tracking controller using Particle Swarm Optimization method.

1.4 Scope of Study

The overall scope of this project will be:

i. The PV system is developed in MATLAB\Simulink® software.
ii. The system utilizes a one-diode type of a PV cell.
iii. The system is only developed for MSX60 module manufactured by Solarex.
iv. The system utilizes 3x1size of MSX60 PV module.
v. The PV system developed with MPPT using PSO method.

1.5 Report Outline

This report consists of five main parts:

(a) Chapter 1: Introduction

This chapter clarifies introduction of this project. also explains the background of this project. This Project also developed MATLAB\Simulink® based photovoltaic (PV) simulator system with partial shading capability. It consists of problem statement, the objectives of the project and its scope.

(b) Chapter 2 : Literature Review

This chapter based on the discussion related to research work which had been done in the past and it compares with findings. This chapter also evaluates the improvements of previous research which compared with the new research.

(c) Chapter 3: Methodology

This chapter discusses the methodology of the project, the design and methods used are clarified in this chapter as well as developing the PV array in MATLAB\Simulink®.

(d) Chapter 3: Result Analysis and Discussion

It presents the result and discussion of the work, practicing the flexibility and accuracy of maximum power point Tracking (MPPT) method which contributes to the achievement of the project's objectives.

(e) Chapter 5: Conclusion and Recommendation

In this chapter conclusion of the project is summarizes, the whole project achievements and determines whole the progress of the project, and also gives recommendation and further actions can be taken for the improvement of the research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter based on the discussion related to research work which had been done in the past and it compares with findings. This chapter also evaluates the improvements of previous research which compared with the new research.

It also focuses on design a photovoltaic module system based on one diode model using MATLAB. A PV system developed with ability to emulate dynamic ecological conditions. The PV system is designed using MATLAB/Simulink® software.

According to several researcher's [6-7],and studies on the features of PV module, the radiation on solar panel can only convert it around 20-30% of efficiency to electrical energy. In order that conquer power loss of solar panels, a MPPT algorithm is required indeed. Dealing on this several studies have been made and proposed on various methods.

2.2 Photovoltaic cell

A photovoltaic cell which is also called as photoelectric cell is a semiconductor (silicon alloys and other materials) device that responsible of converting light to electrical energy. This impact is called by photovoltaic effect. The process of photovoltaic effect starts when the photons of light is greater than the band gap between N-type silicon channel and P-type silicon channel. In result the electron changes the position caused the flow of current. Meanwhile a photovoltaic cell is different from a photodiode because in a photodiode, the light falls on n channel of the semiconductor junction and gets converted into current or voltage signal whereas in photovoltaic cell, it always forward biased [2].

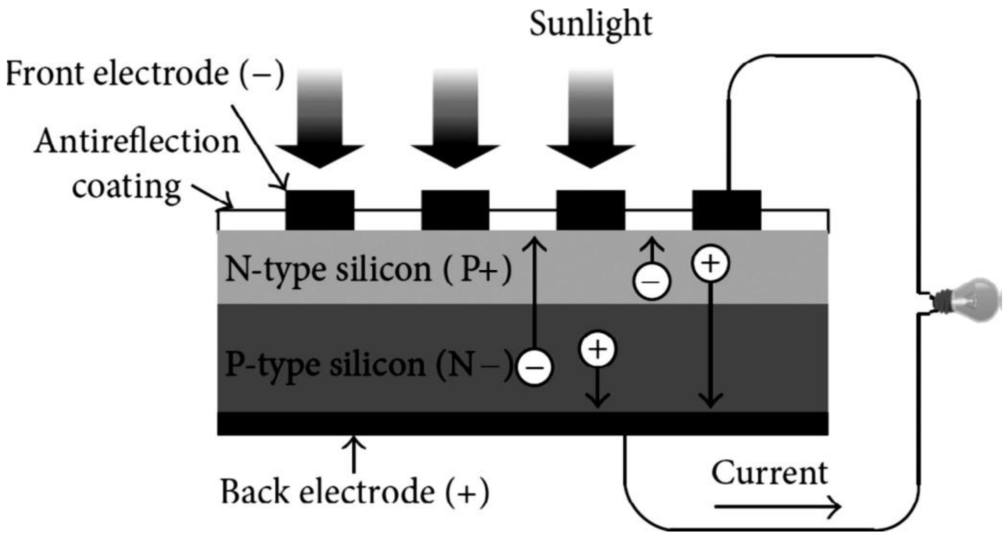

Figure 2.1 : Solar Panel working principle [2]

Crystal silicon is one of the important semiconductor materials that being used to make a solar cell. There are special properties of silicon material, where it has a specific molecular structure. There is a process of doping is used to combine other element with the crystal silicon to achieve a negative or positive charge. This process is carried out because pure crystal silicon is almost neutrally charged, so it would not function well to produce electricity [2].

2.3 PV Models

The foundational power conversion unit of a PV system is the solar cell. Over the past decades, all solar manufacturing companies adapted in silicon material for manufacturing PV cells, even though other materials have been developed. Progresses in manufacture of solar cells are moving so swiftly, for the cells can be classified single crystalline, Polycrystalline and thin film.

The power that gained by a single solar cell is not sufficient for general use since it produces an output voltage less than 1v cells must be connected in series-parallel arrangements to produce sufficient power for high-power applications. They are usually set up into modules. However, there are various sizes of PV modules commercially available in the market; the most commonly used module is 36 to 72 solar cells connected in series to produce enough voltage. For higher power requirement, the modules are interconnected in series/parallel to form array as shown in Figure 2.2.

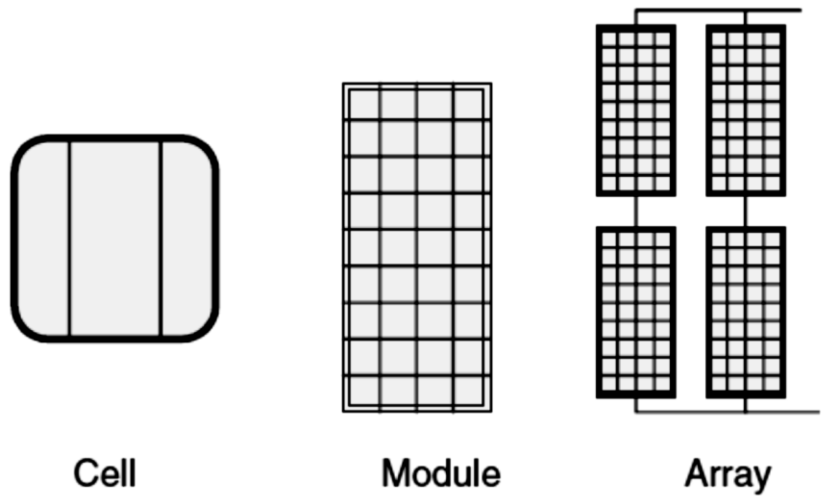

Figure 2.2: Photovoltaic cells, modules, and arrays [1]

2.4 Characteristics of the Photovoltaic Array

The characteristics of photovoltaic based on I-V and P-V having different irradiation with respect to temperature. The most power available has been achieved at the maximum power point (MPP) below the limits of sunlight as well as at the temperature. The I-V characteristics represents the labels of maximum power point (MPP) based on PV module is shown in Figure 2.3.

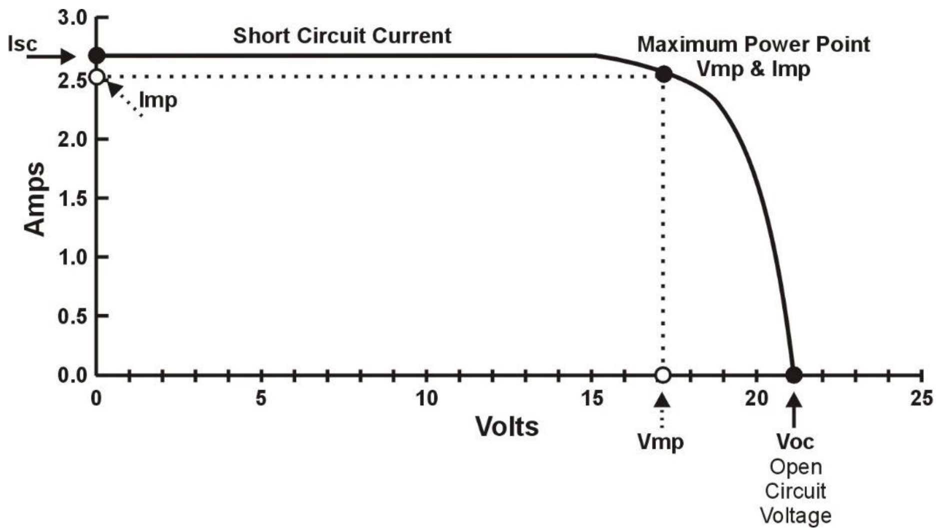

Figure 2.3: sample I-V curve [2]

2.5 Effect of irradiance and temperature

Cloudy weather is the main cause of getting less efficiency from the solar panels because as the irradiance of solar panels is getting decrease the production of power will be decrease. Hence the current keeps lower due to the less radiation of sun light strike on the panels. PV module characteristics having different irradiation based on various MPP is shown in Figure 2.4.

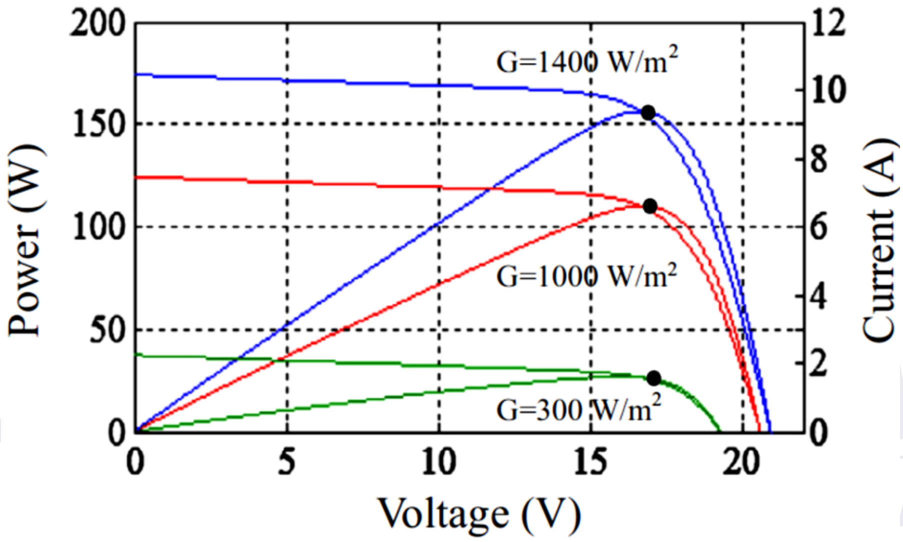

Figure 2.4: Different irradiation curves in PV modules[2]

Meanwhile the flow of efficiency of power should not stopped, mainly the rising of current in PV panels is not caused of decreasing the production of power created using source of panels in fact the voltage drops is the main reason which inefficient to the system. It is better to use the ventilation for solar panels which provide controlling the atmospheric temperature to the system. Characteristics of PV module based on various alternations regarding the atmospheric temperature is shown in Figure 2.5 [2].

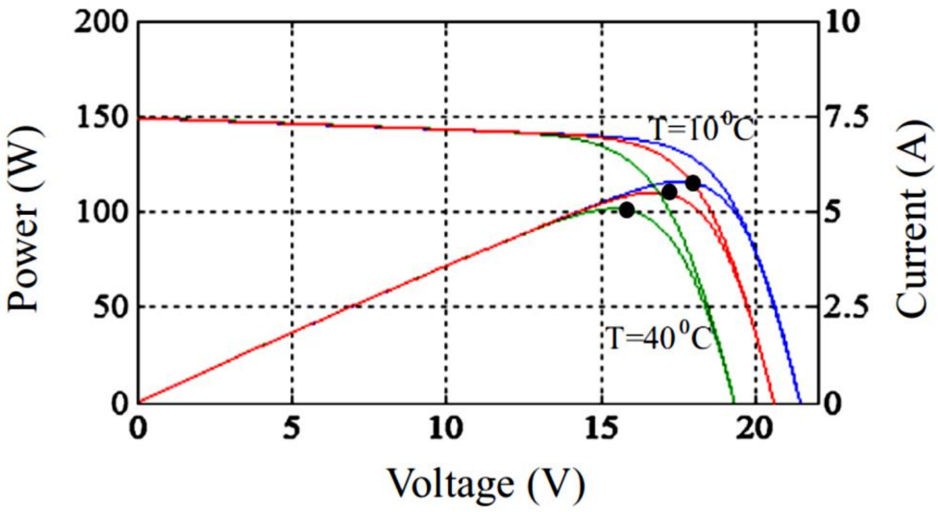

Figure 2.5: Different temperature I-V curves in PV modules[2]

Moreover, the PV modules are dealing with shading effect, the shading effect are the cause of reducing performance of solar panels called shading conditions. The shading condition is analyze when it seen more than a peak that gives various curves which differentiate and compared with condition of ideal PV module based on I-V and P-V curves based on partial condition. These curves measure the total power which makes links to the maximum power point and this will be the local maximum point is shown in Figure 2.6 [1].

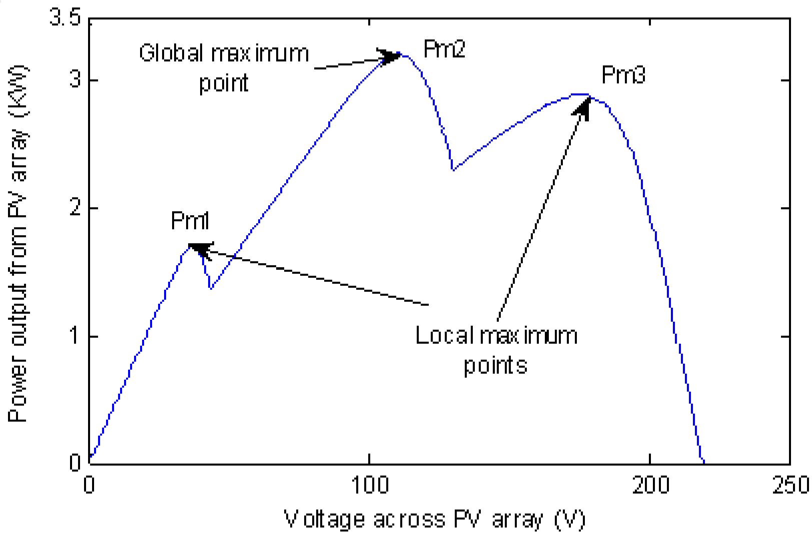

Figure 2.6: I-V and P-V curve under partial shading condition

2.6 Partial shading and by-pass diode

The performance of the output generated power can be affected by shadow on solar panels, by taking consideration in the area occupied by the PV modules, part of them can be covered by trees, natural clouds, some leaves dropped from the tree or other PV modules installed around. In this situation of shading, a PV cell having P-N junction cuts generating energy and it will be passive load, this cell acts as practical diode which stops the current produced by the rest of the cells associated in series, and thus, it will disrupt a whole production of the PV module. To prevent one or more shaded cells to produce a whole string, some diodes which by-pass the covered part of the system are inserted at the PV level. Hence, the operating of the PV module is normal but not in high efficiency, in practical it will be necessary to install a by-pass diode parallel to each single cell, but this will heighten the costs and advantages, hence 2 to 4 by-pass diodes are mostly equipped for each PV module. Figure 2.7shows the function bypass diode in shading condition [1].

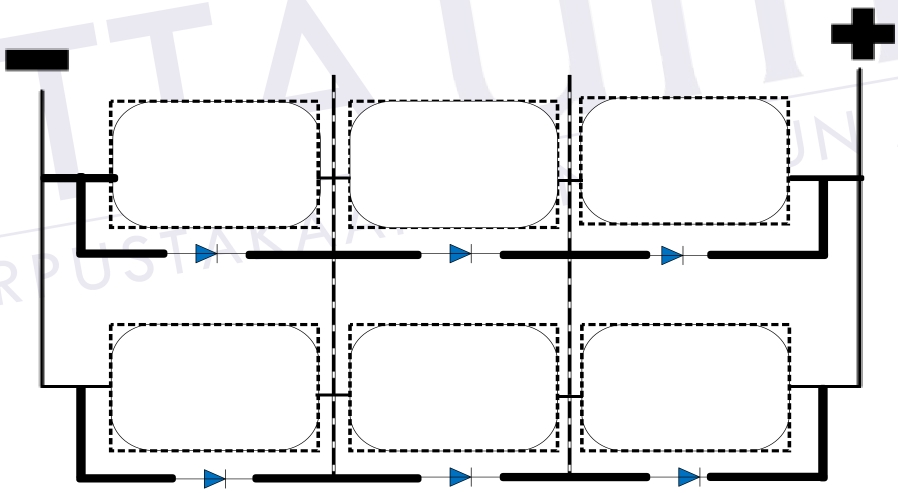

Figure 2.7: Partial shaded PV module with Bypass diode [1]

2.7 Boost Converter

Since MPPT is essentially a load matching problem. A DC-DC converter is required in the section that modifies the panel input resistance to equal the load resistance (adjust the duty cycle). The efficiency of the DC-DC converter has been studied, which is the largest for the speed converter, the largest for the speed converter, the smallest for the boost converter, but because it plan to use the system is bound to the network or loading the required acceptable voltage according to the literature review at the output end, so the boost converter has been chosen to be use [9].

2.7.1 Mode 1 operation of the Boost Converter

The inductor is charged by the battery and stores energy during the closing of the switch. In this mode, the inductor current increases (exponential), but for simplicity, we assume that the charging and discharging operations of the inductor are linear. The diode blocks the current, so the charging current remains fixed and is provided due to the discharge of the capacitor. Figure 2.8 is an operational description of boost converter mode 1 [9].

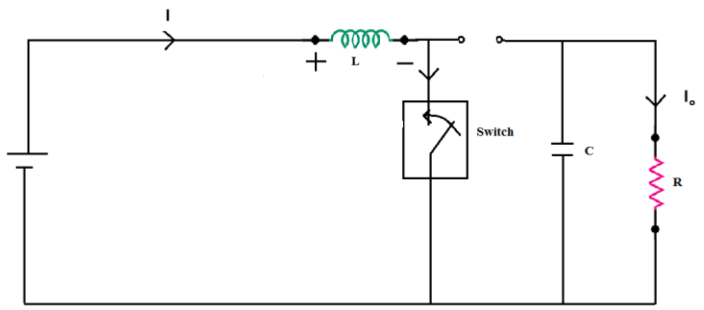

Figure 2.8: Mode 1 operation of Boost Converter

2.7.2 Mode 2 operation of the Boost Converters

In mode 2 the operation of the boost converter, the process is reversible by opening the switch so that current will flow through the diode. When the diode enters its operating state, the inductor becomes discharged, with unequal polarity helping to charge the capacitor. The load current does not change, and it will remain fixed. The function of the boost converter in mode 2 operation is shown in Figure 2.9.

REFERENCES

1. West E 2017 *Final Report*
2. Masters G M 2004 *Renewable and Efficient Electric Power Systems*
3. Ishaque K, Salam Z and Taheri H 2011 Simple, fast and accurate two-diode model for photovoltaic modules *Sol. Energy Mater. Sol. Cells* 95 586–94
4. Villalva M, Gazoli J and Filho E 2009 Comprehensive Approach to Modeling and Simulation of Photovoltaic Arrays *IEEE Trans. Power Electron.* 24 1198–208
5. Chatterjee A, Keyhani A and Kapoor D 2011 Identification of photovoltaic source models *IEEE Trans. Energy Convers.* 26 883–9
6. Ulapane N N B, Dhanapala C H, Wickramasinghe S M, Abeyratne S G, Rathnayake N and Binduhewa P J 2011 Extraction of parameters for simulating photovoltaic panels *2011 6th Int. Conf. Ind. Inf. Syst. ICIIS 2011 - Conf. Proc.* 539–44
7. Roopa P, Rajan S E and Vengatesh R P 2011 Performance analysis of PV module connected in various configurations under uniform and non-uniform solar radiation conditions *2011 Int. Conf. Recent Adv. Electr. Electron. Control Eng. IConRAEeCE'11 - Proc.* 142–9
8. Babu T S, Ram J P, Dragicevic T, Miyatake M, Blaabjerg F and Rajasekar N 2017 Particle Swarm Optimization based Solar PV Array Reconfiguration of the Maximum Power Extraction under Partial Shading Conditions *IEEE Trans. Sustain. Energy* 9 74–85
9. Fathah A 2013 Design of a Boost Converter *Fathah, A. (2013). Des. a Boost Convert. 2. Retrieved from http//ethesis.nitrkl.ac.in/4811/1/109EE0612.pdf* 2
10. Khanna V, Das B K, Bisht D, Vandana and Singh P K 2015 A three diode model for industrial solar cells and estimation of solar cell parameters using PSO algorithm *Renew. Energy* 78 105–13
11. Koad R B A, Zobaa A F and El-Shahat A 2017 A Novel MPPT Algorithm

Based on Particle Swarm Optimization for Photovoltaic Systems *IEEE Trans. Sustain. Energy* 8 468–76

12. Cheng Z, Zhou H and Yang H 2014 Comparison between the Conventional Methods and PSO Based MPPT Algorithm for Photovoltaic Systems *Int. J. Electr. Robot. Electron. Commun. Eng.* 8 887–92
13. Electronics I 2017 Hybrid Mppt Algorithm for Pv Systems Under Partially Shaded Conditions Using a Stochastic Evolutionary Search and *Power Electron. Drives* 2 49–59
14. Bonkoungou D, Koalaga Z and Njomo D 2013 Modelling and Simulation of photovoltaic module considering single-diode equivalent circuit model in MATLAB *Int. J. Emerg. Technol. Adv. Eng.* 3 493–502
15. Ishaque K, Salam Z, Taheri H and Syafaruddin 2011 Modeling and simulation of photovoltaic (PV) system during partial shading based on a two-diode model *Simul. Model. Pract. Theory* 19 1613–26
16. Venugopalan R, Krishnakumar N, Sarjila R and Rajasekar N 2013 Application of Particle Swarm Optimization Technique for the Design of Maximum Power Point Tracking *Adv. Mater. Res. Vol.* 768 47–56
17. Shi J, Zhang W, Zhang Y, Xue F and Yang T 2015 MPPT for PV systems based on a dormant PSO algorithm *Electr. Power Syst. Res.* 123 100–7
18. Solar B 1997 MSX-60 and MSX-64 Photovoltaic Modules